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DEPARTMENT OF AERONAUTICAL ENGINEERING

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
(ADVANCED RESEARCH PROJECTS AGENCY)

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BURNING RATE CONTROL FACTORS

IN SOLID PROPELLANTS

Seventh Quarterly Technical Summary Report

For the Period 1 July 1960 to 30 September 1960

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I. INTRODUCTION

During the past quarter work under this contract has been directed primarily at (1) a continuation of the study of oxidizer particle size effects on burning rate, and (2) the transfer of operations to the newly constructed Solid Propellant Processing Building.

In the previous report, the results of burning rate measurements of several propellants were reported. These propellants were prepared from a number of different fuels, and ammonium perchlorate in various particle size ranges. Particle size ranges were carefully controlled and were incorporated singly and in combination in propellant formulations.

The effect of oxidizer particle size was found to be primarily as expected, that is, burning rate varying inversely with mean particle diameter. However, the occurrence of plateau burning, produced entirely by particle size control, was an unexpected result which could not be readily explained. Because of the practical interest in propellants with low pressure indices, it seemed worthwhile to investigate this phenomenon further and, if possible, to determine the mechanism by which the plateaus are produced. Consequently, particle size studies during the current period have been directed chiefly at plateau propellants. Further experimental results have been obtained indicating more precisely the conditions under which plateaus occur. These results are described in this report. In addition, a theoretical analysis of the plateau burning and of oxidizer particle size effects in general is underway. It is expected that results of this analysis will be presented in the next report.

Construction of the Solid Propellant Processing Building was completed during the past quarter and the facility was essentially ready for operation on the first of October. Only minor modifications to the building and equipment installation remain, and these will be completed without interferring seriously with the research program.

II. EFFECTS OF OXIDIZER PARTICLE SIZE ON BURNING RATE

A. Method of Presentation of Particle Size Data

In order to familiarize the reader with the method of particle size data presentation used in this and previous reports, the subject will be discussed briefly here.

A particle size distribution can usually be described by a set of two parameters which indicate the mean particle diameter and the range of diameters present in the distribution. A few of the systems which have been devised are described by Orr and Dalla Valle in their recently published text on particle measurement.[1] Each of these systems incorporates two parameters which can be used in a mathematical relation describing the distribution of particle sizes.

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[1] "Fine Particle Measurement," Clyde Orr, Jr. and J. M. Dalla Valle, The MacMillan Company, New York, 1959, page 25.

The system employed here also employs two parameters. The parameters have been selected so as to provide a means for easily comparing size distributions without reference to the actual particle size data. The parameters are described in Figure I. The figure contains a cumulative weight distribution of particle diameters in a typical sample of material. Each point on the curve indicates the percent by weight of the sample composed of particles smaller than the diameter corresponding to that point. The parameters employed to describe the distribution are defined in the figure. These are mean diameter (d_m) and width ratio (W.R.). The mean diameter is simply that corresponding to the 50 percent point on the cumulative weight curve. There are several other methods of defining a mean diameter[2], each of which is applicable in special circumstances. However, in this program the size distributions used are narrow and differences between the variously defined mean diameters would be small. Consequently, the selection was made on the basis of convenience.

Having specified the mean diameter of the size distribution, the other parameter, width ratio, indicates the "width" of the distribution about the mean. It is defined as the ratio of diameters corresponding to the 90 and 10 percent points on the cumulative weight curve. A low width ratio indicates a narrow distribution and conversely. The parameter can be related to a geometric standard deviation, but is easier to comprehend for a reader unfamiliar with particle technology.

These two parameters will be used in this report and in the future to describe particle size distribution of propellants used in this program.

B. Further Investigation of Plateau Propellants

Earlier in this program a series of propellants containing a polysulfide fuel-binder were prepared using ammonium perchlorate in narrow particle size fractions. The burning rates of these propellants indicated that the nature of the combustion process changes as pressure and particle size are varied. Regions of behavior were apparent, each of which demonstrated combustion characteristics different from the others. Perhaps the most interesting region was that based on propellants containing fine particles and burning at high pressures. It was in this region that plateau behavior and, in some cases, extinguishment were observed. Similar results were obtained with propellants containing different fuel-binders. All these results were presented in the previous report.

During this past quarter, the investigation of this plateau behavior has continued. A series of propellants were prepared with varying oxidizer concentration to determine the effect of this variable on the plateau behavior. All propellants were prepared from finely ground oxidizer, and two different fuel-binders were used. Burning rates of these propellants are shown in Figures 2 and 3. A similar study is in progress with polyesterstyrene propellant; results will be presented in a later report.

The polysulfide propellants indicate a transition of high pressure behavior as the oxidizer content is increased. At low oxidizer content extinguishment

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[2] "Micromeritics, The Technology of Fine Particles," J. M. Dalla Valle, Pitman Publishing Corporation, New York, 1948, page 43.

occurs. At higher contents the plateau behavior is observed and this gradually disappears at the highest oxidizer concentration.

The range of oxidizer concentrations used with the epoxy propellants was limited. However, it was sufficient to indicate a transition from plateau behavior to non-plateau burning. The transition occurs very abruptly with these propellants.

The results indicate that the region of plateau behavior is sensitive to oxidizer content as well as particle size. It appears desirable to explore this region further by varying particle size at other oxidizer concentrations, both lower and higher than the 65 percent used in the investigation thus far.

LIST OF ILLUSTRATIONS

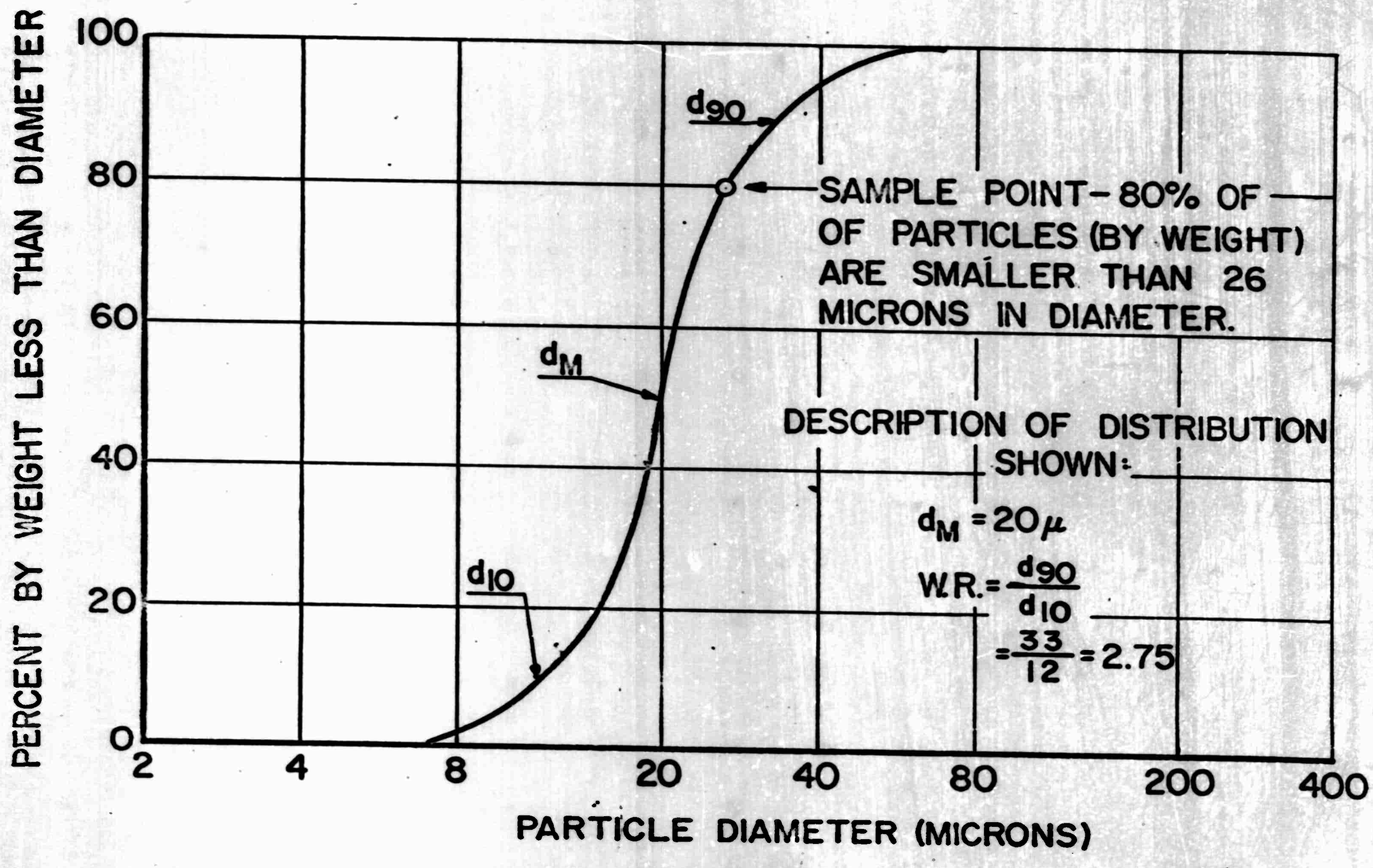

FIGURE I – SAMPLE PARTICLE SIZE DISTRIBUTION SHOWING METHOD OF DATA PRESENTATION AND DEFINITIONS OF TERMS

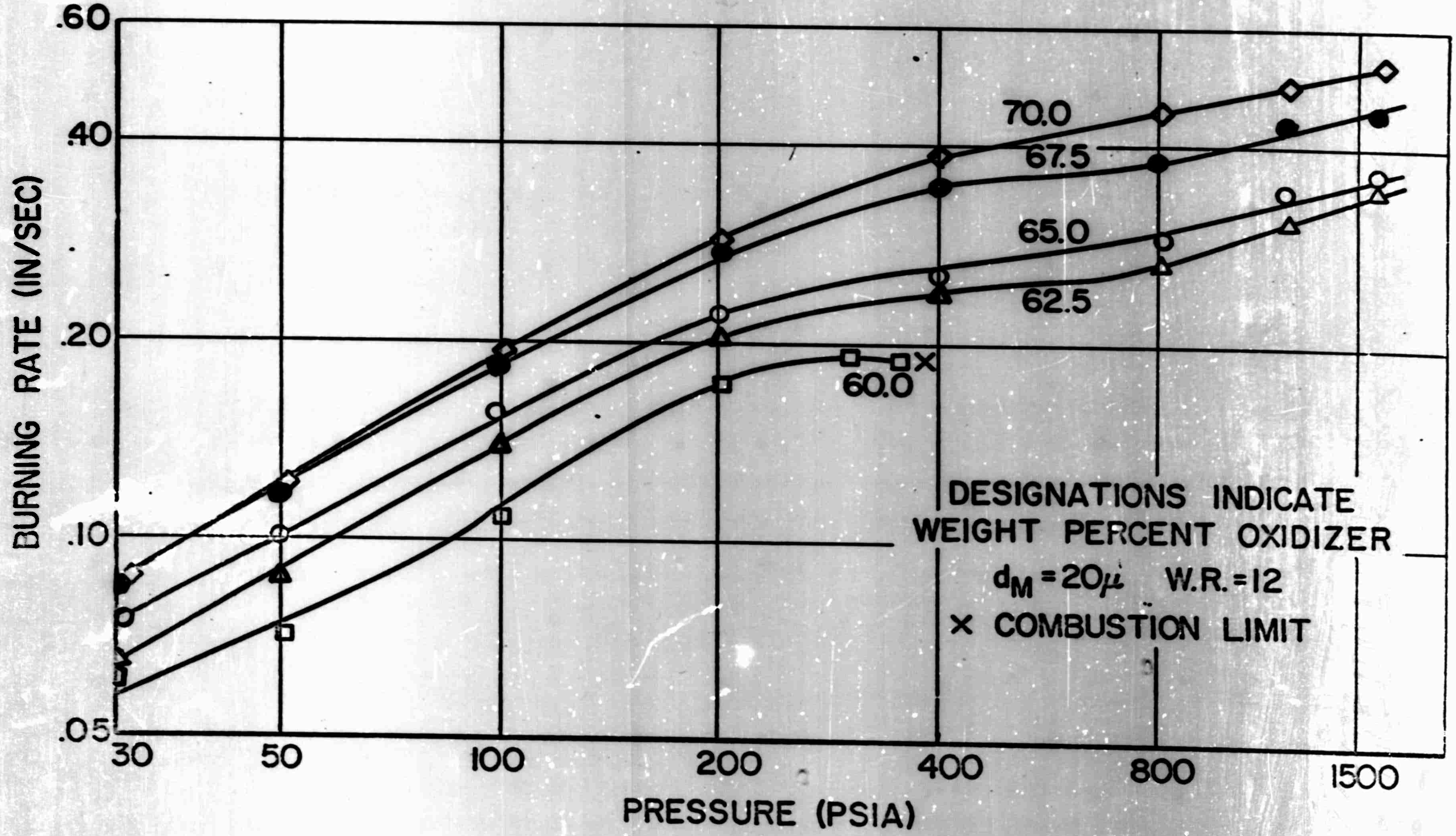

FIGURE 2 – BURNING RATE VS PRESSURE, POLYSULFIDE PROPELLANTS WITH VARYING OXIDIZER CONCENTRATION, FINE PARTICLES

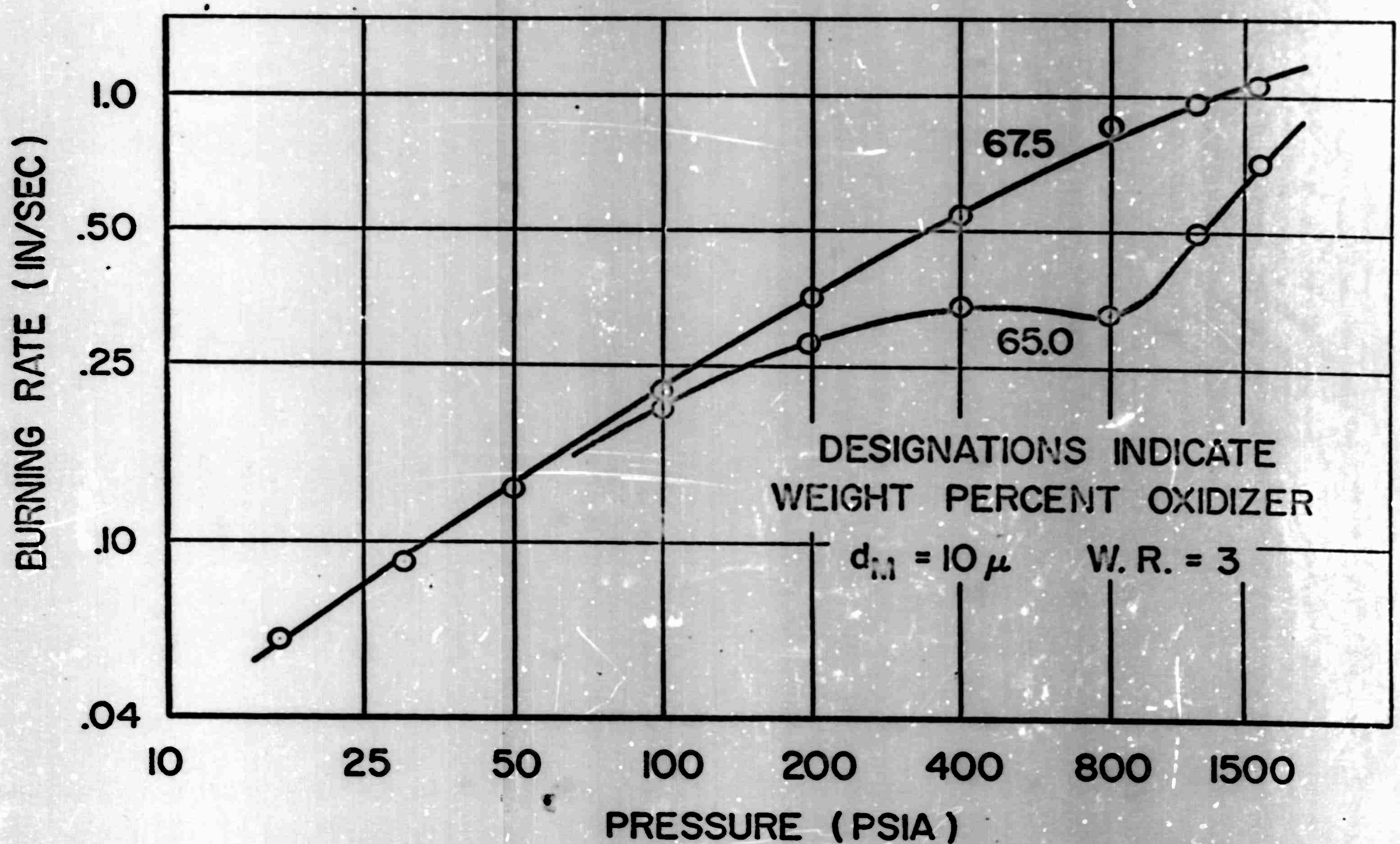

FIGURE 3 BURNING RATE VS PRESSURE, EPOXY PROPELLANTS WITH VARYING OXIDIZER CONCENTRATION

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